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SYSTEM AND METHOD FOR STATISTICAL DESIGN OF ULTRASOUND PROBE AND IMAGING SYSTEM

BACKGROUND OF THE INVENTION

[0001] This invention generally relates to ultrasound imaging systems. In particular, the invention relates to the design of ultrasound transducer probes for use in an ultrasound imaging system.

[0002] Designing the probe in an ultrasound imager is a difficult task because of the large number of factors involved. A typical probe comprises several layers whose dimensions determine its mechanical and electrical behavior. Prior art [see, e.g., R. E. McKeighen, "Optimization of Broadband Transducer Designs by Use of Statistical Design of Experiments," IEEE Trans. Ultrasonics, Ferroelectrics and Frequency Control, Vol. 43, No. 1, pp. 63-70 (1996)] has described statistical means to seek optimal behavior of the impulse response of the device. However, this work neglects the increasingly significant coupling between the imager parameters and the probe design. Particularly when the aperture is divided into several rows in the slice thickness [elevation] dimension, such as in active matrix arrays, the image quality consequences of such coupling becomes acute. The business requirement is for a jointly optimal probe and image-parameter design, in which the variability of image quality (image quality) is minimally impacted by manufacturing tolerances. These tolerances strongly influence the production costs. A comprehensive method for achieving these objectives is needed.

[0003] The matching of a new prototype probe to a given ultrasound imager is highly resource-intensive. Typically, an engineer manually varies parameters such as the F-numbers for each focal zone and receive depth, in order to improve image quality parameters such as image uniformity, detail and contrast resolution, etc. One way to increase an imager's value to the customer is by providing preset parameter sets with which the physician can rapidly set the machine up for a given examination. To maximize the image

quality potential, a modern imager may have several thousand parameters affecting each preset. There is a need for a process of choosing these parameters that can be at least partially automated for new probes. This process should also allow more mundane tasks, such as the porting of a probe to a new platform, to be completely automated. Several months of time-to-market advantage can be realized using such a method, as well as an improvement in engineering productivity.

SUMMARY OF THE INVENTION

[0004] The present invention comprises a process and a computer system that allow the performance of a probe and imager combination to be specified and jointly optimized in image quality terms. The designs produced optimize both the image quality and other CTQ (critical to quality) parameters, such as the distribution of regulatory power indices and mechanical index. These CTQs indirectly affect image quality through their effect on patient dose.

[0005] The computer system in accordance with the preferred embodiment of the invention has the following features and capabilities:

(1) The ability to capture and model not just a few design parameters of an ultrasound transducer, but hundreds of them, and not just "best guess" values, but actual values taken from the databases of real probes that are in daily use.

(2) The ability to model the behavior of a transducer design in a complete system context, including details such as the aperture opening schedule, number of available system channels, number of focal zones, their depths, and the depths at which data from multiple zones is to be spliced together; as opposed to modeling only the transducer in isolation.

(3) The ability to integrate the one-dimensional acoustic stack design (KLM model) with the full system model, and to allow acoustic stack

parameters (e.g., number of matching layers, their thicknesses and material properties) to be simultaneously optimized along with system-related properties (e.g., focal zone depths, F numbers) in a single DOE (design of experiment) run. Traditionally, the acoustic stack is optimized using CTQ parameters such as bandwidth and sensitivity, and then the optimization of the aperture and lens is done separately.

(4) The ability to do true statistical design, as opposed to "point" design. That is, being able to simulate the statistical distribution of quality measures (CTQs) and to calculate their sensitivity to variations in design parameters. This ability allows one to create "robust designs" which are not only optimized, but are resistant to performance degradation caused by manufacturing variation.

[0006] The invention further comprises a method and computer system for choosing imaging parameters to be included in preset parameter sets for new transducer probes.

[0007] In addition, the invention is directed to a Transducer Design Advisor comprising a graphical user interface for facilitating selection of a parameter set to be used in a simulation. The user selects a desired parameter set by navigating across and interacting with a succession of windows. The user specifies various geometric characteristics of the transducer and how the user wants to simulate the imager system. Finally, the user specifies weights for the various CTQs at different depths. Based on these inputs, the Transducer Design Advisor creates the files needed by the ultrasound simulator.

[0008] The invention further comprises a method for speeding up the probe design process via a comprehensive simulation and an intelligent "wizard".

[0009] The invention also comprises an automated method for optimizing transducer geometry and imager parameters based on a cost